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AD-A032 343

Advanced Electronic Technology

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15 Aug 76

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT
TO THE
AIR FORCE SYSTEMS COMMAND

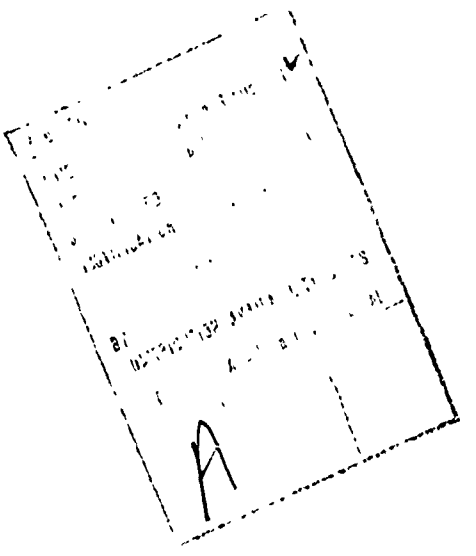
1 MAY - 31 JULY 1976

ISSUED 17 SEPTEMBER 1976

LEXINGTON MASSACHUSETTS

INTRODUCTION

This Quarterly Technical Summary covers the period 1 May through 31 July 1976. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.



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CONTENTS

DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 May through 31 July 1976 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

Seismic Discrimination	ARPA/NMRO
Education Technology	Bureau of Mines, ARPA/HRRO
Speech Evaluation	OSD-DCA
Network Speech	OSD-DCA
Digital Voice Processing	AF/ESD
Packet Speech	ARPA/IPTO
Communications Adaptive Internetting	ARPA/IPTO
Radar Signal Processing Technology	ARMY/BMDATC

M. A. Herlin
Head, Division 2

A. J. McLaughlin
Associate Head

DIGITAL COMPUTERS
GROUP 23

I. INTRODUCTION

Seven custom gate array circuits were in various stages of design and fabrication during this quarter, and significant yield improvements were obtained. Progress was made on the development of the poly-ox isolation technique.

II. APPLICATIONS

A. Gate Array Custom Circuits

The status of the five custom ECL gate array circuits designed for a speech synthesizer is as follows:

(1) Four-phase clock generator – seven devices tested good on the wafer prober in the second lot of wafers and are being packaged for dynamic testing

(2) 4-bit arithmetic-logic unit – working masks are being made from reticles

(3) 4-bit register transfer unit – the first lot of wafers is in processing

(4) Control A – tapes have been generated for reticle plotting

(5) Control B – a new layout is being done because of extensive logic changes by the designer.

Additional multiplier and multiplier control circuits were fabricated.

B. Sequential Radar Data Memory Circuit

Test chips of the memory-cell and shift-register portions of the sequential memory being constructed under BMDATC sponsorship have been tested. The single memory cell has the necessary low β in its lateral n-p-n transistor and operates correctly. However, because there are no on-chip accessing circuits and parasitic capacitances of external circuits dominate, dynamic performance cannot be evaluated. The shift register on the test chip had an oscillating bias generator. A rework of second-level metal is being implemented on wafers of one run in the hope of suppressing the oscillation and thus making it possible to test the circuit.

C. MNOS Capacitor Memory Arrays

Successful storage and readout have been accomplished in a 0.09- × 0.15-mil intersection in a simulated 200 × 200 bit MNOS capacitor array. The array consisted of a 5 × 5 array of various-width word and digit lines and a sixth wide line in each dimension to simulate the capacitive loading of the additional lines. A resistor-diode two-level AND gate circuit is currently being considered for on-chip partial decoding of large MNOS capacitor arrays. This circuit requires two diodes and one resistor for each row and column in the array. It is possible to implement this circuit without fanout, and thus without a significant decrease in overall array density. Utilizing this circuitry, a 10^6-bit array would require 190 leads, and a 10^8-bit array

would require 600 leads to the initial decoding operation which can be performed off-chip. Experiments are proceeding to evaluate the performance and practicality of this approach. A test circuit was designed and built to apply repetitive write, disturb, and read waveforms to MNOS capacitors in order to observe device degradation due to multiple write pulses, and charge storage decay either with time or multiple disturb pulses.

D. Quantizer

Quantizers have been packaged and tested for use in a 30-MS/sec 6-bit A/D converter. Six of these converters are to be assembled in one module for use with the TRADEX radar. Fifty quantizers were supplied to an Air Force contractor for backup to their own processing of devices from our masks.

E. Peak Detector

An integrated circuit for measuring power levels was built and operated up to 80 MHz. This is a commonly required circuit in satellites and, although it has only seven transistors, is awkward to implement with discrete components.

III. INTEGRATED CIRCUIT PROCESSING

A. Gate Array Processing and Yield Analysis

Pre-metallization wafer tests were implemented in order to select gate array wafer runs for first- and second-level metal customization. Transistor current gain and leakage data were obtained from each wafer, after contact opening, by testing the diffusion characterization transistor; the photolithographic quality was then assessed by a sample visual inspection. Eight out of ten runs were selected for additional processing and were patterned into five multiplier, one multiplier control, and two phase generator runs. Since functional devices were obtained from three multiplier lots, the one control and the second phase generator lot, we have shown that a variety of gate array devices can be produced from wafers characterized and selected before metallization.

The gate array yield increased significantly during this quarter. In order to quantitatively assess the factors limiting the yield and the effects of process and device design refinements introduced in the last quarter, we formulated a preliminary model which utilized selected device and transistor test data as well as visual inspection of wafers and defective circuits to calculate six process yields. The yields were related to silicon epitaxy defects, unsatisfactory diffusion or oxidation properties, broken or extraneous photolithographic patterns, misaligned patterns, first- to second-level metal insulator defects, and original mask defects. When the model was applied to those runs tested during the quarter, we found the primary reasons for improved yield to be significantly reduced photo pattern defects, improved alignment, increased current gain to offset the effects of minor level 3-6 misalignment, and a reduction in insulator rotox defects.

B. Photolithography

Slight dimensional changes in the buried collector mask, permitting more margin for cumulative alignment error, have been made. Recent improvement in array yields may have been partially due to this change.

C. Dielectric Isolation

The specific cause of excessive transistor leakage in poly-ox isolated gate chains has been identified as inversion of the p-type base along the vertical oxide sidewall connecting the n-type collector and emitter regions. Two solutions have been experimentally verified. One has been the use of a p-type channel stopper, diffused or implanted, using either boron or gallium. The other solution is to ion-implant the base dopant, thereby minimizing subsequent high-temperature processing and outdiffusion into the oxide. The presence of epi-poly interfaces does not seem to have any adverse effects on transistor performance.

D. Self-Aligned Transistors

Ion implantation has been incorporated into the small-geometry transistor processing. The arsenic emitter is implanted and annealed first, and then either a gallium or boron base is implanted through the emitter using the same oxide window. Gallium is of interest as a base dopant because its high diffusion constant in oxide gives it desirable channel-stopping qualities. Transistors have been made using a single gallium implant as both a base and a channel stopper. Other transistors have been produced with boron-implanted bases showing f_T peaks as high as 3.94 GHz.

E. Packaging

Eutectic bonding of the 0.238- × 0.253-in. array dice has been unsuccessful due to excessive fracturing of the silicon during the scrubbing of the die on the gold preform. Smaller (0.098 × 0.104) dice do not crack.

A low-viscosity, high-thermal-conductivity epoxy has been shown to provide a void-free bond with excellent adhesion. The successful reduction of lid brazing temperatures has eliminated epoxy degradation during bonding.

IV. DESIGN AND TESTING

A. Gate Array Cells

The number of gate array cells in the library now exceeds fifty. Some of these are no longer used while others are minor variations of basic types, such as cells which incorporate frequently used connections between gates within a cell, thereby simplifying interconnect wiring. The cell types are summarized as follows:

(1) I/O buffers	6
(2) Bias generator	1
(3) Versions of AND (negative logic) gates	22
(4) Exclusive-OR gate	1
(5) Inverters or buffer drivers	4
(6) Master-slave flip-flops	3
(7) Latch flip-flops	2
(8) Clock drivers	3
(9) Decoder	1

For each cell, there exists in the CAD library the following information: mask geometry, mnemonic layout overlay, logic diagram, and schematic diagram.

B. Gate Array Testing

The gate array has 24 I/O cells, each containing an input and an output buffer. Four of the five speech synthesizer circuits required more than 24 inputs and less than 24 outputs; thus, on these circuits, some bonding pads are disconnected from an output transistor and used to connect a package pin directly to an interior gate input. This nonstandard usage, unfortunately, results in a proliferation of tester adapter hardware.

Our present manual preparation of test sequences has been quite time consuming for some of these circuits.

C. Integrated Injection Logic

Large upward n-p-n betas (B_u) are most important for good I^2L device operation. The principal parameters which control B_u are:

(1) n-p-n base sheet rho which should be made as large as possible with punch-through as the limiting factor.

(2) Buried layer sheet rho which should be made as small as possible consistent with the ability to grow good epi material over it.

(3) The number and area of base metal contacts which must be kept to a minimum and, more importantly, p^+ base inserts must be used at least under the region(s) of base metal contacts.

A mask set has been designed to test I^2L circuits made according to (more or less) standard ECL design and processing rules. This set includes gate chains to measure delays as well as devices to evaluate operating parameters. Tests have been specified.

COMPUTER SYSTEMS
GROUP 28

An expanded automatic error-tracking facility has replaced a tedious and limited manual system during this quarter. The value of error-recording facilities for diagnosing and repairing specific major system failures is obvious. The value of error recording for the diagnosis of intermittent or long-cycle problems has often been ignored. A major reason for this is the fact that the information is either poorly summarized or not summarized at all. Typically, a great deal of information is collected and recorded on a single event, such as a correctable read error on a disk drive. On a daily printout, such information is condensed to a simple count of the number of occurrences. An option to print a detailed record is available, but not usually invoked because the existence of a few correctable or temporary errors on a given day is not a normal cause for concern. Further, when dealing with equipment where the media is interchangeable, as on a disk or tape drive, it is difficult to determine whether the media or the drive is at fault. This causes a delay in taking any corrective action because the source of the problem has not been identified.

During this quarter, a program was developed to present error information in the form of a 30-day window sorted both by media and by device. Trends and patterns, if they exist, are easily discerned. Errors which may be overlooked on a day-to-day basis can be evaluated in the context of a 30-day performance period. The nebulous definitions of "acceptable" or "normal" performance are replaced by comparisons with other similar devices or with recent past performance of the same device. Further refinements of this tracking technique are being developed.

Local implementations of new versions of the VM time-sharing system and VS batch-processing system have been completed. Among the improvements provided by the new VM system is that of greater operating efficiency through greater sharing of code. In earlier versions, a separate copy of a given subsystem was loaded into the virtual memory of each user who invoked it. For a popular subsystem such as the text editor, a number of simultaneously active users unnecessarily burdened the VM paging facility by swapping multiple copies of the same code. In the new VM system, all self-modifying code has been removed from the EDIT program, the EXEC processor, and the VS simulation routines so that a single copy of each may be shared by any number of users. This reduces the paging load and increases the responsiveness of the system.

As previously reported, a new version of VS has been installed to operate as a batch-processing capability under VM. This new version, known as VS1, was designed to perform more efficiently with VM than the Lincoln standard VS2 system. However, two large structural analysis systems, important to the Laboratory's work programs, were found to be incompatible with VS1. This meant that VS2 had to be retained for evening batch processing. Users and systems programmers were required to deal with the two different versions of the operating system – VS1 during the day and VS2 at night. The problem, involving differences in memory management techniques, has been resolved and VS1 is now replacing VS2 as the Lincoln standard batch-processing system.

Preparations continue for next quarter's installation of IBM 3350 disk drives. Because these disks are permanently mounted, a great deal of planning has gone into storage layout and backup procedures. The layout must permit both VM and VS, with their respective user files, to coexist and operate without mutual interference. The problem of providing backup protection becomes more critical and more time consuming as the amount of on-line storage increases. Procedures are being developed that will permit backups of VM files during VS production running. Since most of the day-to-day changes occur in the VM files, this will save several hours a week of separate backup operations. The preparations have also included equipment moves and electrical work to permit overlap of the old and new disk systems.

SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 May through 31 July 1976. The Solid State Research Report for the same period describes the work of Division 8 in more detail. Funding is primarily provided by the Air Force, with additional support provided by the Army (BMDATC), ARPA (MSO, IPTO), NSF, and ERDA.

A. L. McWhorter
Head, Division 8

I. Melngailis
Associate Head

DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 May through 15 August 1976

PUBLISHED REPORTS

Journal Articles

JA No.			
4469A	Low-Threshold Transversely Excited NdP_5O_{14} Laser	S. R. Chinn J. W. Pierce H. Heckscher	Appl. Opt. 15, 1444 (1976)
4539	Interpretation of Infrared Modulation Spectroscopy Data in Graphite by the Slonczewski-Weiss-McClure Band Model	M. S. Dresselhaus* G. Dresselhaus	Phys. Rev. B 13, 4635 (1976)
4544	Threshold Ambiguities in Absorptive Laser Damage to Dielectric Films	R. H. Picard* D. Milam* R. A. Bradbury* J. C. C. Fan	Chapter in Laser Induced Damage in Optical Materials (NBS Special Publication, 1976), p. 272, Proc. 7th Symp. on Damage to Laser Materials, Boulder, Colorado, 29-31 July 1975
4570	Thermal Faceting of (110) and (111) Surfaces of MgO	V. E. Henrich	Surf. Sci. 57, 385 (1976)
4572	Crystal Structure and Fluorescence Lifetime of Potassium Neodymium Orthophosphate, $K_3Nd(PO_4)_2$, a New Laser Material	H. Y-P. Hong S. R. Chinn	Mater. Res. Bull. 11, 421 (1976), DDC AD-A026811
4573	Acoustoelectric Convolvers for Programmable Matched Filtering in Spread-Spectrum Systems	J. H. Cafarella W. M. Brown, Jr. E. Stern J. A. Alusow	Proc. IEEE 64, 756 (1976)
4574	The Schottky Diode Acoustoelectric Memory and Correlator – A Novel Programmable Signal Processor	K. A. Ingebrigtsen	Proc. IEEE 64, 764 (1976), DDC AD-A028456
4576	Vibrational Energy Relaxation in Liquid N_2–CO Mixtures	S. R. J. Brueck R. M. Osgood Jr.	Chem. Phys. Lett. 39, 568 (1976), DDC AD-A028459
4581	Surface-Acoustic-Wave Resonators	D. T. Bell* R. C. M. Li	Proc. IEEE 64, 711 (1976), DDC AD-A028460
4583	Properties and Applications of Reflective-Array Devices	R. C. Williamson	Proc. IEEE 64, 702 (1976), DDC AD-A028461

* Author not at Lincoln Laboratory.

JA No.			
4584	Room-Temperature cw Operation of GaInAsP/InP Double-Heterostructure Diode Lasers Emitting at 1.1 μm	J. J. Hsieh J. A. Rossi J. P. Donnelly	Appl. Phys. Lett. 28, 709 (1976), DDC AD-A028550
4585	Infrared Third-Harmonic Generation in Molecular Gases	H. Kildal T. F. Deutsch	IEEE J. Quantum Electron. QE-12, 429 (1976)
4601	Uniform-Carrier-Concentration p-Type Layers in GaAs Produced by Beryllium Ion Implantation	J. P. Donnelly F. J. Leonberger C. O. Bozler	Appl. Phys. Lett. 28, 706 (1976), DDC AD-A028457
4604	Low-Loss GaAs $p^+n^-n^+$ Three-Dimensional Optical Waveguides	F. J. Leonberger J. P. Donnelly C. O. Bozler	Appl. Phys. Lett. 28, 616 (1976) DDC AD-A027103
4612	Intracavity Second-Harmonic Generation in a Nd Pentaphosphate Laser	S. R. Chinn	Appl. Phys. Lett. 29, 176 (1976)
4616	Excitation of Polyatomic Molecules by Radiation	D. M. Larsen N. Bloembergen*	Opt. Commun. 17, 254 (1976)
4617	A Re-examination of the CS_2 Laser	T. F. Deutsch H. Kildal	Chem. Phys. Lett. 40, 484 (1976)
4620	Observation of Two-Dimensional Phases Associated with Defect States on the Surface of TiO_2	V. E. Henrich G. Dresselhaus H. J. Zeiger	Phys. Rev. Lett. 36, 1335 (1976)
4626	High-Efficiency Ion-Implanted Lo-Hi-Lo GaAs IMPATT Diodes	C. O. Bozler J. P. Donnelly R. A. Murphy R. W. Laton R. W. Sudbury W. T. Lindley	Appl. Phys. Lett. 29, 123 (1976)
4633	Multistrip Coupling to SAW Resonators	R. C. M. Li J. A. Alusow	Appl. Phys. Lett. 29, 129 (1976)

Meeting Speeches

MS No.			
2951H	Conceptual Phase Diagrams and Their Applications to Itinerant Electron Magnetism	J. B. Goodenough	In Magnetism in Metals and Metallic Compounds (1976), J. T. Lopuszanski, A. Pekalski, and J. Przystawa, Eds. (Plenum, New York, 1976), pp. 35-90
4190	The Physics and Equivalent Circuit of the Basic SAW Resonator	R. C. M. Li J. A. Alusow R. C. Williamson	In 1976 IEEE-MTT-S International Microwave Symposium Digest (IEEE, New York, 1976), p. 280

*Author not at Lincoln Laboratory.

MS No.			
4194	Surface-Acoustic-Wave Device for Doppler Filtering of Radar Burst Waveforms	J. Melngailis R. C. Williamson	In 1976 IEEE-MTT-S International Microwave Symposium Digest (IEEE, New York, 1976), p. 289

* * * * *

UNPUBLISHED REPORTS

Journal Articles

JA No.			
4591	Doppler-Limited and Atmospheric Spectra of the 4 μm $\nu_1 + \nu_3$ Combination Band of SO_2	A. S. Pine P. F. Moulton	Accepted by J. Mol. Spectrosc.
4611	Laser-Induced Surface Damage of Infrared Nonlinear Materials	H. Kildal G. W. Iseler	Accepted by Appl. Opt.
4618	Transient InSb Spin-Flip Laser – A Measurement of T_1	S. R. J. Brueck A. Mooradian	Accepted by Opt. Commun.
4623	High-Efficiency, High-Average Power Second-Harmonic Generation with $CdGeAs_2$	N. Menyuk G. W. Iseler A. Mooradian	Accepted by Appl. Phys. Lett.
4636	Selective Black Absorbers Using MgO/Au Cermet Films	J. C. C. Fan P. M. Zavracky	Accepted by Appl. Phys. Lett.
4637	Phenomenological Theory of Raman Scattering in Europium Chalcogenides	S. A. Safran* G. Dresselhaus B. Lax*	Accepted by Solid State Commun.
4640	Fabrication Techniques for Surface Wave Devices	H. I. Smith	Accepted as Chapter in Acoustic Surface Waves (Springer-Verlag)
4641	Distributed Feedback $Pb_{1-x}Sn_xTe$ Double-Heterostructure Lasers	J. N. Walpole A. R. Calawa S. R. Chinn S. H. Groves T. C. Harman	Accepted by Appl. Phys. Lett.
4643	Direct Optically Pumped Multiwavelength CO_2 Laser	M. I. Buchwald* C. R. Jones* H. R. Fetterman H. R. Schlossberg*	Accepted by Appl. Phys. Lett.
4653	Tunable Infrared Laser Sources for Optoacoustic Spectroscopy	P. L. Kelley	Accepted as Chapter in Optoacoustic Spectroscopy and Detection, Y-H. Pao, Ed. (Academic Press)
4661	Relaxation Oscillations in Distributed Feedback Lasers	S. R. Chinn	Accepted by Opt. Commun.

* Author not at Lincoln Laboratory.

Meeting Speeches†

MS No.			
4059D	Photoelectrolysis of Water by Solar Energy	D. I. Tchernev	12th Informal Conf. on Photochemistry, National Bureau of Standards, Gaithersburg, Maryland, 28 June – 1 July 1976
4067G	Recent Advances in Tunable Infrared Lasers	A. Mooradian	Conference on Tunable Lasers and Applications, Loen, Nordfjord, Norway, 7-11 June 1976
4174A	Optically Pumped Gas Lasers	H. Kildal T. F. Deutsch	
4181A	Transient InSb Spin-Flip Laser	S. R. J. Brueck A. Mooradian	
4124	Analog Memory Correlators for Radar Signal Processing	E. Stern	AGARD Symposium, The Hague, Netherlands, 14-18 June 1976
4140A	Photoelectrolysis of Water	J. G. Mavroides	Symposium on Solar Energy Utilization, M. I. T., 12 May 1976
4177A	Selective Surfaces for Solar-Energy Applications	J. C. C. Fan	
4229A	Zeolite Adsorption Systems for Solar Heating and Cooling	D. I. Tchernev	
4268	Capturing the Sun Through Bio-Conversion	T. B. Reed	
4269	Thin-Film Photovoltaic Cells	H. J. Zeiger	
4140B	Photoelectrolysis of Water	J. G. Mavroides	ERDA Workshop on Solar Energy, University of Houston, Texas, 16-19 May 1976
4169, 4169A	Ion Beam Etching	H. I. Smith	Electrochemical Society, Washington, D. C., 2-7 May 1976; Annual Symposium on Advances in Sputtering, Ion Etching and Related Vacuum Technology, Burlington, Massachusetts, 9 June 1976
4174	Progress in Optically Pumped CO Transfer Lasers	T. F. Deutsch H. Kildal	Ninth International Quantum Electronics Conference, Amsterdam, The Netherlands, 14-18 June 1976
4175	Enhancement of Optically Pumped Far Infrared Lasing by Stark Modulation	H. R. Fetterman C. D. Parker P. E. Tannenwald	
4181	Transient InSb Spin-Flip Laser	S. R. J. Brueck A. Mooradian	

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
4182	Vibrational Energy Relaxation in Liquid N_2–CO Mixtures	S. R. J. Brueck R. M. Osgood, Jr.	Ninth International Quantum Electronics Conference, Amsterdam, The Netherlands, 14-18 June 1976
4183	Fluorescence and Lasing Properties of $NdNa_5(WO_4)_4$, $K_3Nd(PO_4)_2$ and $Na_3Nd(PO_4)_2$	S. R. Chinn H. Y-P. Hong	
4184	Infrared Third Harmonic Generation in Molecular Gases	H. Kildal T. F. Deutsch	
4185	Sixteen Micrometer CO_2 Laser	R. M. Osgood, Jr.	
4187	SubDoppler Molecular Beam Infrared Spectroscopy with Tunable Diode Lasers	A. S. Pine K. W. Nill	
4216	The Possibility of Laser Oscillation in Ar-HCN Mixtures	E. Zamir* A. Szoke* R. M. Osgood, Jr.	
4300	Direct Optically Pumped Multiwavelength CO_2 Laser	M. I. Buchwald* C. R. Jones* H. R. Fetterman H. R. Schlossberg*	
4177B	Sputtered Films for Solar Energy Applications	J. C. C. Fan	Annual Symposium on Advances in Sputtering, Ion Etching, and Related Vacuum Technology, Burlington, Massachusetts, 9 June 1976
4177C	Wavelength-Selective Surfaces	J. C. C. Fan	M. I. T. Alumnus Day, Cambridge, Massachusetts, 4 June 1976
4178A	New Solid Electrolytes	H. Y-P. Hong J. A. Kafalas K. Dwight J. B. Goodenough	Superionic Conductor Conference, Schenectady, New York, 9-12 May 1976
4182A	Vibrational Energy Relaxation in Liquid N_2–CO Mixtures	S. R. J. Brueck R. M. Osgood, Jr.	31st Symposium on Molecular Spectroscopy, Ohio State University, Columbus, 14-18 June 1976
4205	Design of Reflective-Array Surface Wave Devices	J. Melngailis R. C. Williamson J. Holtham R. C. M. Li	European Workshop on the CAD of SAW Devices, Bologna, Italy, 7-9 April 1976
4229	Solar Energy Applications of Natural Zeolites	D. I. Tchernev	Zeolite '76, Tucson, Arizona, 6-13 June 1976
4230	$Ga_xIn_{1-x}As_yP_{1-y}$/InP Double-Heterostructure Lasers	J. A. Rossi J. J. Hsieh J. P. Donnelly	1976 Device Research Conference, Salt Lake City, Utah, 21-23 June 1976

* Author not at Lincoln Laboratory.

MS No.			
4252	Distributed Feedback $Pb_{1-x}Sn_xTe$ Double-Heterostructure Lasers	J. N. Walpole A. R. Calawa S. R. Chinn S. H. Groves T. C. Harman	1976 Device Research Conference, Salt Lake City, Utah, 21-23 June 1976
4272	GaAs $p^+n^-n^+$ Directional Couplers and Electrooptic Switches	F. J. Leonberger J. P. Donnelly C. O. Bozler	
4236A	Minority Carriers in Graphite	M. S. Dresselhaus* G. Dresselhaus	American Physical Society Meeting, Washington, D. C., 8-10 June 1976
4238	Preparation of Polycrystalline Si Thin Films by Laser Crystallization	J. C. C. Fan H. J. Zeiger P. M. Zavracky	National Workshop on Low Cost Polycrystalline Silicon Solar Cells, Southern Methodist University, Dallas, Texas, 18-19 May 1976
4238C	Thin Film Photovoltaics	H. J. Zeiger J. C. C. Fan	ERDA Meeting, University of Maine, Orono, 2 August 1976
4243	Vapor Phase Growth of $Hg_{1-x}Cd_xTe$ Epitaxial Layers	P. Vohl C. M. Wolfe	1976 Electronic Materials Conference, University of Utah, Salt Lake City, 23-26 June 1976
4244	Temperature-Gradient LPE Growth of $Pb_{1-x}Sn_xTe$ and $PbS_{1-y}Se_y$	S. H. Groves	
4246	Electrical and Optical Properties of $CdGeAs_2$	G. W. Iseler H. Kildal N. Menyuk	
4243A	Vapor-Phase Epitaxial Growth of $Hg_{1-x}Cd_xTe$ $(0 < x < 1)$ Layers on CdTe Substrates	P. Vohl	ARPA – Materials Research Council Meeting on Epitaxy, La Jolla, California, 12-13 July 1976
4329	Liquid-Phase Epitaxial Growth of Lattice-Matched GaInAsP/InP for 1 → 1.3 μm Double-Heterostructure Lasers	A. J. Strauss	
4254	Efficient Infrared Nonlinear Mixing with Applications to Optical Intelligence, Countermeasures and Laser Radar	N. Menyuk H. Kildal G. W. Iseler	Seventh Classified Conference on Laser Technology, U. S. Military Academy, West Point, New York, 8-10 June 1976
4257	Solar Thermal Materials	T. B. Reed	Symposium on Ceramics in the Service of Man, Carnegie Institution, Washington, D. C., 7-9 June 1976

* Author not at Lincoln Laboratory

MS No.			
4261A	Defect Surface States on TiO_2: Two-Dimensional Surface Phases	V. E. Henrich G. Dresselhaus H. J. Zeiger	36th Annual Conference on Physical Electronics, University of Wisconsin, Madison, 7-9 June 1976
4262	The Physical Properties of Cadmium Telluride	A. J. Strauss	International Symposium on CdTe, Strasbourg, France, 29 June – 2 July 1976
4280	CdTe Optical Waveguide Modulators	D. L. Spears A. J. Strauss	
4265A	Lasing and Fluorescence in High-Nd-Concentration Materials	S. R. Chinn	Seminar, Universität Hamburg, Germany, 21-22 June 1976
4270	Electron Spectroscopy of Surface States in Metal Oxides	V. E. Henrich	Seminar, Bell Laboratories, Murray Hill, New Jersey, 7 May 1976
4274	Infrared Lasers and Their Applications	P. L. Kelley	VIII National Conference on Laser and Nonlinear Optics, Tbilisi, USSR, 25-28 May 1976
4293	Thickness, Composition and Surface Morphology of III-V Compound Semiconductor LPE Layers	J. J. Hsieh	Gordon Research Conference on Crystal Growth, Andover, New Hampshire, 12-16 July 1976
4331	Semiconductor Lasers	J. N. Walpole	Lecture for "Lasers & Optics for Applications" Course, Aeronautics Department, M. I. T., 22 July 1976

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

A GaAs $p^+n^-n^+$ directional-coupler switch has been developed which is operable both as a passive coupler with 98-percent power transfer and as an optical switch. The switch is characterized by 17-dB power isolation and by constant total power output (within 0.2 dB) throughout the switching-bias range.

HgCdTe photodiodes have been characterized at high frequency for use as gigahertz-response CO_2 laser heterodyne receivers. In order to evaluate device uniformity and sensitivity, the following measurements were carried out: pulse response vs frequency, high-frequency raster scan profiles, RF noise output as a function of detector bias and frequency, direct heterodyne detection, and blackbody heterodyne radiometry. These measurements show that it is necessary to use high-frequency characterization to get an accurate picture of the high-frequency performance of these devices, and that low-frequency measurements can give misleading results.

A temperature-gradient liquid-phase epitaxial growth apparatus for $Pb_{1-x}Sn_xTe$ has been constructed and utilized. For the growth of $Pb_{1-x}Sn_xTe$ films on PbTe substrates, the imposed temperature gradient (a) does not improve the film quality of heteroepitaxial growths in the $Pb_{1-x}Sn_xTe$ system, and (b) does not have a measurable effect on the Sn/Pb ratio of the grown film.

II. QUANTUM ELECTRONICS

Low-threshold, CW lasing has been obtained in $NdNa_5(WO_4)_4$, $K_3Nd(PO_4)_2$, and $Na_3Nd(PO_4)_2$. Laser thresholds and efficiencies are given for these new compounds, together with fluorescent lifetimes, as a function of Nd concentration for crystals in which Nd is replaced by La.

Substantial narrowing of the Doppler width of molecular absorption lines has been observed in an effusive molecular beam from a capillary array nozzle using broadly tunable diode lasers. Hitherto unresolved Λ-doublet splittings in the $^2\pi_{3/2}$ electronic ground state of NO have been studied.

The performance of the vibrational energy transfer lasers optically pumped by doubled CO_2 radiation has been improved. Slope efficiencies close to unit quantum efficiency and output energies up to 13 mJ have been demonstrated for the CO-CO_2 system. Laser action has been observed on a new transition in CS_2; by pumping the 10^01 level directly, operation was obtained on the $10^01 \rightarrow 10^00$ transition at 6.6 μm.

Considerable progress has been made in the HBr-pumped 16-μm CO_2 laser. The pulse energy has been scaled to 120 μJ. In order to demonstrate that the 16-μm laser can be made stepwise tunable, laser action in the $^{13}C^{16}O_2$ isotopic series has been obtained. The threshold for the 9.6-μm stimulating pulse has been measured to be ~3 mJ, indicating that a rather large but conventional sealed-off Q-switched laser would be sufficient for driving an isotopic 16-μm laser. Kinetic measurements of the relaxation of the 16-μm lower level indicate that its relaxation time is of the order of 10^{-5} sec at typical pressures. As a result, high-repetition-rate operation of the laser is possible.

Experimental work on the quantum electronics of cryogenic liquids has progressed along three avenues: (a) measurement of the vibrational kinetics of molecules in liquid solutions;

(b) observation of laser-induced photochemistry in several liquid hosts; and (c) measurement of the infrared spectra of various dopant molecules. The results indicate that laser photochemistry in liquid media could have practical applications.

III. MATERIALS RESEARCH

In order to obtain a better understanding of the mechanism of the photoelectrolysis of water in cells with TiO_2 anodes, the interaction of adsorbed H_2O molecules with TiO_2 surfaces is being investigated by ultraviolet photoemission spectroscopy. Comparison of the spectra for Ar-bombarded TiO_2 before and after exposure to water vapor indicates that the H_2O molecules form bonds to the oxygen vacancies produced by bombardment.

The effect of cesiation on the work function of CdTe is being studied in order to determine the possibility of producing negative-electron-affinity CdTe surfaces that can be used to make transferred-electron photocathodes with a graded-gap $Hg_xCd_{1-x}Te$ structure. In initial experiments, a reduction of 2.4 eV in the work function of both n- and p-type CdTe has been obtained by a series of alternate exposures to Cs and O_2.

A preliminary study has been undertaken to assess the potential of insulator-metal transitions for utilization in optical switching devices such as modulators and switchable diffraction gratings for use as variable-wavelength filters. Modulation at 151 μm and 337 μm has been achieved with devices employing thermally switched VO_2 films deposited by reactive sputtering on sapphire substrates.

IV. MICROELECTRONICS

Considerable attention has been given to the problem of improving yields in CCD processing. Wafers of 30- × 30-cell, prototype imaging arrays have been fabricated with improved processing techniques, and have exhibited yields of over 90 percent when tested for diode leakage and gate-to-gate and gate-to-substrate shorts. Dynamic testing of these devices will result in a somewhat lower yield, but the results of static testing are very encouraging.

Several 30- × 30-cell, prototype imaging arrays have been dynamically tested using an electrical input signal. The capability of inserting signals electrically is a useful addition to a CCD imaging device, and costs little in terms of added device area. Electrical inputs are simpler and more effective than optical inputs in setting clocking voltages for optimum operation and for measuring charge transfer efficiency. Transfer efficiencies of 0.9998 or greater have been measured for the output registers of several devices, and the transfer efficiency for a single complete device has been determined to be equivalently high.

Impurities have been gettered from semi-insulating gallium arsenide using silicon- and neon-ion-implantation damage and a subsequent 16-hr anneal at 750°C. The amount of gettering was determined by an evaluation of epitaxial layers grown on the gettered samples after removal of the damaged material. Impurity profiles of layers grown on these surfaces show a dramatic reduction in the outdiffusion of compensating impurities from the substrate into the epitaxial layer. It is possible that this ion-implantation-damage gettering will be useful in providing better substrates for application to gallium arsenide microwave FETs. In addition, because the gettering effects occur in the temperature range for epitaxial growth and ion-implantation anneals, this gettering phenomenon could also be important in understanding and improving growth and annealing procedures.

V. SURFACE-WAVE TECHNOLOGY

The use of Cu_L radiation for x-ray lithography has been demonstrated. For replicating patterns with linewidths of the order of 1000 Å, it is preferable to use softer x-ray radiation than that obtained from the commonly employed aluminum targets. The use of the characteristic L radiation (13.3 Å) emitted from a copper target increases the attenuation in the mask absorber pattern and reduces the range of randomly directed Auger and photoelectrons that are excited when the exposing x-ray is absorbed. Because of the high absorption at longer wavelengths, special x-ray masks with thin low-absorption membranes were employed.

A second generation of pulse expanders and compressors has been developed for the MASR (Multiple-Antenna Surveillance Radar) system. These reflective-array devices generate and compress linear-FM waveforms with a duration of 150 μsec, bandwidth of 10 MHz, and time-bandwidth product of 1500. The use of bismuth-germanium-oxide (BGO) substrates allowed 150 μsec of dispersion to be obtained in a relatively compact device. Because of the large time-bandwidth product, it was necessary that the pulse expanders have especially low loss. By careful design of the transducers and reflection gratings, overall CW insertion loss for the expanders was held to 30 dB. This provided 60 dB of signal-to-noise in the expanded waveform. A complete subsystem containing six dispersive lines has been assembled for the MASR system.

A dual acoustoelectric convolver for decoding differential-phase-shift-keyed (DPSK) data has been developed for the ARPA Packet Radio System. This device decodes DPSK data which have been spread to a 100-MHz bandwidth by means of continuously changing pseudorandom, bit-encoding waveforms. The bit rate is 100 kbps. DPSK decoding is provided by splitting a standard convolver structure into two segments and comparing the phase of the signal from the two segments in a sum-difference hybrid. Improved packaging techniques provide temperature stability and are compatible with commercial fabrication procedures.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESD-TR-76-227	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Advanced Electronic Technology		5. TYPE OF REPORT & PERIOD COVERED Quarterly Technical Summary 1 May -- 31 July 1976
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Melvin A. Herlin and Alan L. McWhorter		8. CONTRACT OR GRANT NUMBER(s) F19628-76-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element No. 65705F Project No. 649L
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		12. REPORT DATE 15 August 1976
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electronic Systems Division Hanscom AFB Bedford, MA 01731		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

digital computers	Lincoln Terminal System	laser research
integrated circuitry	computer systems	quantum electronics
magnetic films	solid state devices	microelectronics
education technology	materials research	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This Quarterly Technical Summary covers the period 1 May through 31 July 1976. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.

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